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Adaptation Approaches to Climate Change in China: An Operational Framework[1]

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ABSTRACT: Climate change poses great risks for China, which makes adaptation an essential response. However, adaptation planning and implementation are still at a preliminary stage with respect to the theoretical framework and methodology. This article focuses on the status, problems and basic needs as regards adaptation to climate change, and outlines the operational framework that the government is seeking to pursue for China's adapting to climate change. The conclusion is that, to satisfy the basic needs of development, it is necessary to clarify development-oriented and incremental adaptation. Furthermore measures to enhance adaptive capacity can be classified as infrastructure-based, technology-based and institutional. Lastly the authors stress the importance of appraising adaptation actions and measures from an economic perspective.

KEYWORDS: Adaptation; Incremental adaptation; Development-oriented adaptation; Approaches for adaptation; Economic analysis of adaptation.

JEL classification: Q54, Q56, Q58.

Enfoques de adaptación al cambio climático en China: un marco operativo

RESUMEN: El cambio climático plantea grandes riesgos para China, lo que hace que la adaptación al mismo sea una respuesta esencial. No obstante, la planificación y la puesta en práctica de esta adaptación se encuentran aún en una fase preliminar con respecto al marco teórico y a la metodología. El presente artículo se centra en la situación, problemas y necesidades básicas de la adaptación al cambio climático, y presenta un esbozo del marco operativo que pretende seguir el gobierno para la adaptación de China a este cambio. La conclusión es que, para satisfacer las necesidades básicas del desarrollo, es necesario aclarar el concepto de la adaptación orientada al desarrollo e incremental. Además, las medidas para mejorar la capacidad de adaptación se pueden clasificar como medidas basadas en la infraestructura, basadas en la tecnología e institucionales. Por último, los autores destacan la importancia de evaluar las acciones y medidas de adaptación desde una perspectiva económica.

PALABRAS CLAVES: Adaptación; Adaptación incremental: Adaptación orientada al desarrollo; Enfoques para la adaptación; Análisis económico de la adaptación.

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1. Introduction

China has a vast territory with a long coastline. As a rapidly developing country with the largest population in the world, it has low per capita resource availability, coupled with vulnerable ecosystems, as a result of which the country will surely face more severe challenges because of climate change. Furthermore, China is now at a crucial stage of implementing the "moderate prosperity" program, and increasing climate risks have to be seen in the context of accelerating urbanization, industrialization and rising residential energy consumption. In this context, reducing development costs, preventing potential risk and improving the ecological environment are potential major challenges for China in terms of improving its capacity to adapt to climate change.

China is at an early stage with regard to developing analytical methodology, policy, and planning for climate change adaptation. In its national climate change program, China has declared that it sees mitigation and adaptation as equally important responses to climate change. It also considers that action in this area must be part of an interrelated structure of policies that deal with overall economic development. Thirdly, climate action on all fronts must place due emphasis on advancement and innovation in science and technology (People's Republic of China, 2007).

This paper provides an adaptation framework for climate change that is consistent with these broad goals and objectives. It consists of a structured approach to formulating and implementing adaptation strategies, policies and measures to ensure human development in the face of climate change and take fully into account the current situation, problems and basic needs. The paper reflects the current thinking of the government with respect to how to address adaptation, but its main contribution is to offer some guidance on how the broad framework can be applied in specific cases. The paper also distinguishes between two types of adaptation: developmental-based and incremental adaptation, and three types of adaptation measures: infrastructural, technological and institutional. The paper is organized as follows. Sections 1 and 2 provide an introduction and set out the operational framework. Sections 3 and 4 discuss the methodology and present some typical adaptation cases in China. Section 5 concludes this report by presenting some suggestions on climate change adaptation and policies that conform to the current stage of social economic development of China.

2. Operational Framework for Adaptation to Climate Change

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportuni-

ties" (Smit et al., 2001)[1]. The objectives of adaptation are to: (1) improve adaptive capacity; (2) reduce the vulnerability to climate change; and (3) exploit potential development opportunities. The first two purposes are short-term goals of adaptation, while the third is a long-term goal of adaptation that should be pursued in accordance with sustainable development (CEPS, 2008). So, adaptation responses to climate change and sustainable development imply a close two-way relationship: choices about development pathways influence climate change as well as the vulnerability of societies and economy to climate change impacts; on the other hand, sustainable development can reduce vulnerability to climate change by enhancing adaptive capacity and increasing resilience, and adaptive policies can only be successfully implemented within a sustainable development framework.

There have been many studies that have addressed adaptation to climate change; however, few of them explicitly attempt to separate the concept of adaptation from that of development (see Markandya and Watkiss, 2009). In fact, to give an exact definition of adaptation rather than confuse adaptation with development has been suggested as a particularly important aspect, so as to make the analysis of adaptation to climate change and its policy implications deeper and clearer. In this study, we argue that adaptation to climate change can be categorized into two aspects - namely *developmental-oriented* and *incremental* adaptation, yet strictly speaking the classical definition of adaptation applies only to the latter kind. We also consider it useful to classify adaptation solutions in three different modes: infrastructure-based, technology-based and institutional approaches respectively. Different combinations of these will be required, depending on the sector and type of adaptive activity.

Incremental adaptation refers to the additional resources and measures required to address newly-emerging risks, taking the present system as given. Climate change may increase the frequency and intensity of climate risks, making the existing facilities inadequate and necessitating additional investment. It should be noted that the purpose of incremental adaptation is precisely to address newly-added climate risks since regular risks have been considered in the process of satisfying basic development requirements. For instance, in the developed countries or regions, the infrastructure has been designed to withstand extreme natural disasters, such as embankment and facilities related to flood and drought; however, the incremental risks induced by climate change have not yet been accounted for. For example, when sea level rises by 20 cm, additional inputs are required to heighten and consolidate the existing dams. These are referred to as the inputs for incremental adaptation.

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[1] The Fourth Assessment report retains the definition from the Third Assessment quoted above and focuses on vulnerability and adaptive capacity. Likewise the UNDP offers a very similar definition, stressing that it consists of strategies in response to climate change **"Adaptation** is a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented." (UNDP, 2005). The UNFCCC at its Cancun Meeting in 2010 set up the Cancun Adaptation Framework, which stressed the need for action in this area based on international cooperation, "to reduce vulnerability and build resilience in developing country Parties, taking into account the urgent and immediate needs of those developing countries that are particularly vulnerable." See http://unfccc.int/adaptation/cancun_adaptation_framework/items/5852.php

Nevertheless, in most developing and less-developed countries and regions, the infrastructure is either non-existent or not robust enough to withstand most impacts of current climate hazards, let alone future climate change. Due to natural climate variability, economic development is bound to result in an increase in the engineering and technological inputs that are in place, even without climate change. For example, in coastal areas a shortage of flood control facilities and techniques and drought-proof crops, and poorly built houses increase the vulnerability of communities. In most cases, the vulnerability comes from inadequate public investment, a lack of awareness and weak capacity of governance; moreover all these factors are more prevalent the more under-developed the country is (Brooks *et al*., 2004). Accordingly, adaptation in vulnerable areas needs to provide strong support to address climate change and promote the capacity to deal with extreme climate events by strengthening 'hardware' infrastructure, developing stress-resistant crop varieties and constructing high-quality housing for disaster prevention and other adaptive countermeasures. Adaptation in these cases should place equal emphasis on both normal development and newly-emerging risks, and both these aspects are integral components of the strategy for coping with climate change. For example, a "one-time-design, one-time-investment" may be required to build up a new sea embankment or dam even if there is no sea level rise, just to cope with the current fluctuations in tidal flows. Such investment is referred to as development-oriented adaptation. If in addition a sea-level rise of 20 cm is expected further investment will be required and the additional investment is referred to incremental adaptation.

The differences between the two concepts of incremental adaptation and development-oriented adaptation can be explained numerically (see Table 1). Assume that the system faces not only regular climate risks but also climate change risks. In the Business as Usual (BAU) scenario, with no additional climate risk, developed areas are totally able to respond to regular climate risks with an investment of 60. In developed countries such an investment is in fact made, but in developing countries the investment made is only 30, leaving an 'adaptation deficit' of 30. With climate change the additional investment needed in developed countries is 30 since the regular risk has already been covered. In developing regions, however, the total investment required with climate change is 60, since there is also a deficit of 30 to be covered. This is what we mean by development-oriented adaptation. In other words, in the climate change scenario, adaptation in developed regions just needs to increase the investment to address the newly-added risks of climate change, while investment in less-developed regions must combine part of the regular risks with newly-emerging risks. The "adaptation deficit" caused by low levels of development explains in part why adaptation to climate change has been regarded by developing countries as an additional development cost brought on by the historical emissions of developed countries (UNEP, 2009)[2].

[2] An adaptation deficit arises when the current infrastructure is inadequate to cope with the present climatic variations (e.g., present flood defences are inadequate to cope with present flooding). Action to correct this situation can possibly be justified even without reference to future climate change (although it may still not be the top priority) (Parry *et al*., 2009). The notion of development adaptation is closely related to that of an adaptation deficit. The main difference is that with development adaptation the action is designed to meet both the deficit as well as any addition risks posed by further climate change.

TABLE 1

Incremental Ada

Adaptation type	Status quo (BAU scenario)	Scenarios of future change
Incremental adaptation (developed regions)	Regular risk: 60 Climate change risk: 0 Investment in adaptation: 60 Climate-related net loss: 0	Regular risk: 60 Climate change risk: 30 Investment in adaptation: 90 Climate-related net loss: 0
	Incremental investment required:0	Incremental investment required:30
Development-oriented adaptation (less-developed regions)	Regular risk: 60 Climate change risk: 0 Investment in adaptation: 30 Climate-related net loss:30	Regular risk: 60 Climate change risk: 30 Investment in adaptation: 30 Climate-related net loss: 60
	Incremental investment required:30	Incremental investment required:60

Note: (1) Adaptation inputs are assumed to be proportional to efficiency, i.e. one unit of adaptive input can reduce the corresponding risk level by one unit; (2) Inevitable risks are ignored.

In view of different recognition about climate change, adaptation can be further divided into 'no regrets' or 'low regrets' measures and 'climate justified' measures (OECD, 2009). In fact, development-oriented adaptation contains many 'no' or 'low' regrets measures (e.g., eliminate poverty, reduce air pollution, conserve bio-diversity, protect water resources, and enhance public health system) which aim to enhance adaptive capacity. Even though these adaptive actions might over-evaluate the climate risks, they are still indispensable in the process of socio-economic development[3].

Incremental adaptation closely related to 'climate change justified' actions, might be warranted in cases where there is considerable sensitivity to climate change variables that can be predicted with sufficient reliability under different scenarios of social economic development. In other words the action has a robust defense in terms of benefits under a wide range of possible scenarios. Examples would include the case for thickening and heightening a dam, migration from flood diversion areas and change of land-use mode in zones threatened by floods, guided by the prediction for sea-level rise.

As a developing country in the process of rapid urbanization and industrialization, there is remarkable disparity in economic development between different regions of China, which means that it is faced with enormous demand for both incremental

[3] As noted, no-regrets actions are those that one would wish to take for other reasons and that also have benefits in terms of reducing the impacts of possible climate change. If these actions are truly justified on other grounds then the uncertainty of their climate benefits is of no consequence as it does not impact on the decision. Such cases, however, are very rare; in most circumstances, the action can be modified to increase the climate adaptation benefits and there is a choice to be made of how far such modification is justified. Nevertheless actions such as investing in female education, which the World Bank found helped significantly in reducing the consequences of extreme weather events (World Bank, 2009), can reasonably be described as no-regrets options from the climate viewpoint and need not be influenced by uncertainties about the nature of the impacts of such weather events.

and development-oriented adaptation in some regions. Although well developed with large accumulated wealth, dynamic economic performance and relative well-equipped infrastructure facilities, the coastal areas of China are still inadequately protected from current risks and additionally face increasing risks from climate change. Accordingly, it is essential to allocate funds to cover development adaptation - for example, to maintain and reinforce present infrastructures such as dams – and to cover the additional risks and resist the threat.

This type of combination of adaptation – both development and incremental – is characteristic of most less-developed countries/regions, which have the primary, top-priority task of increasing financial support in various infrastructure establishments to promote development-oriented adaptation. Measures in this regard often consist of construction and upgrading of dams and increasing investment in water conservancy; strengthening meteorological monitoring construction; reinforcing transportation and energy facilities; promoting policy insurance and expanding the scope of social security for vulnerable groups.

Adaptation to climate change involves a complex collection of measures. Generally speaking, there are three types of tool for adaptation to changing climate: engineering, technological and institutional. Different methods are employed according to various adaptation requirements in different climate risk zones and different sectors /industries.

- Engineering adaptation measures increase the adaptive capacity of socio-economic systems by strengthening engineering constructions such as water conservancy facilities, environmental infrastructures, inter-basin water transfer project, disease-monitoring networks, meteorological monitoring stations, and so on. Such measures typically involve major investments in physical capital.
- Technological adaptation measures indicate improving adaptive capacity by enhancing scientific research and technological innovation. Measures in this regard include assessment of climate risks, exploitation of new stress-resistant varieties, development of bio-technologies, disease prevention and control technology, risk monitoring and early-warning technology.
- Institutional adaptation measures seek to improve the enabling environment in a society by setting-up and improving related policies and legislation, reform of administration and governance systems, exploration of financing resources, making the best use of taxation, supervision and management, and so on. Examples include the provision of institutional guarantees for enhancing adaptive capacity through carbon taxes, carbon sequestration forestry, watershed eco-compensation, weather insurance, social security, education and training, popularization of science and other incentive measures.

In agriculture, the engineering adaptation tool mainly involves the construction of agricultural infrastructures such as water conservation projects in large-scale irrigation districts as well as small-scale infrastructure facilities (e.g., energy-saving ecological farm irrigation projects, water resource facilities aiming to relieve drought

in small-scale irrigation areas and non-irrigation districts). In addition, by evaluating climate change risks associated with different sectors, industries and regions, technological adaptation measures emphasize the research and development of new technologies, new products, new crop varieties and new management methods in order to reduce the losses to agriculture from climate risks. Finally, the institutional adaptation system is an effective way to enhance disaster emergency management**,** and further improve agricultural disaster prevention and mitigation systems by means of policy, legislation, setting up of agencies, funding, and other approaches.

3. Economic Analysis of Adaptive Activities regarding Climate Change

Adaptation to climate change is a long-term, continual process. China will give full consideration to climate change issues by integrating adaptation policies and actions into its social and economic condition, climate risk and regional development programme as it strives to push forward adaptive activities in a coordinated way.

We believe that an important component of this assessment of possible adaptation measures is an economic analysis of the benefits and costs, including gainers and losers. The OECD has recently developed a Policy Guidance document with information and advice on how to facilitate the integration of adaptation into development processes (OECD, 2009), which describes projected adaptation as a process that involves four basic, iterative steps: (1) identify the present and future climate risks and vulnerability; (2) identify possible adaptation measures; (3) assess and select feasible adaptive options; (4) evaluate the "successful" adaptive actions. Socio-economic analysis of climate adaptation is **imperative** in all the above steps.

One way of identifying climate risks and vulnerability is to estimate the economic costs of climate risks; at the same time, various assessment methods are available under different climate risk scenarios. From an economic point of view, there are two main analytical methods: micro-analysis via a bottom-up approach and macro-analysis via a top-down approach (Nunes and Ding, 2009). The micro-analysis method involves estimating the total economic losses related to climate risks that a specific industry or group may suffer, based on an empirical-statistical methodology (e.g., field-based research methods, econometric methods, environmental impact evaluation methods, and so on) at sectoral, project and individual levels. In contrast, the analysis method based on macro-level data and information employs tools such as computable general equilibrium models (CGE), input-output methods and macro econometric methods to reveal important economy-wide linkages between climate risks and economic influence. This is called the macro-analysis method.

It is necessary to do a cost-benefit analysis or a cost-effectiveness analysis in order to select the optimal adaptive measures (Pearce *et al*., 1996). Cost-benefit analysis involves weighing the total expected economic and non-economic costs against the total expected benefits of one specific action and gauging the efficiency of the intervention relative to the status quo so as to make the best decision. If the benefits outweigh the costs, then the action is feasible, but not otherwise.

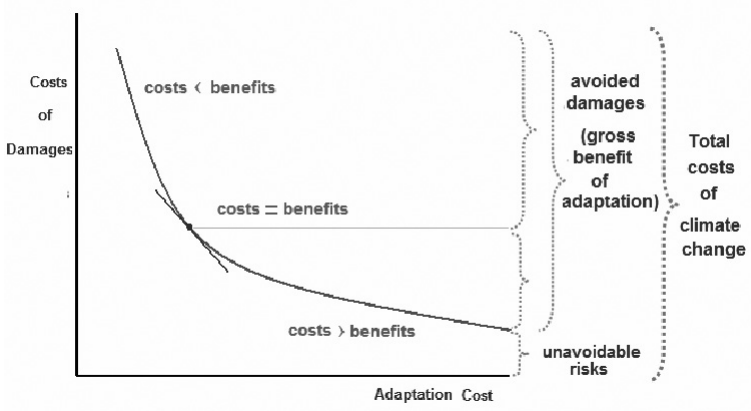
Closely related, but slightly different, is cost-effectiveness analysis, which is an analysis of the cost of different alternatives in order to see whether an adaptive action can significantly reduce the costs of achieving a given goal (e.g., a measure of vulnerability). Effective adaptation measures must possess a certain degree of flexibility, which may help to ensure that the expected goals are in fact achieved under climate variability and changing socio-economic conditions.

Finally any cost-benefit or cost-effectiveness analysis should take account of the co-benefits of adaptation measures. These can be very important: for example, planting trees for the climatic objective of providing a shelterbelt can also conserve water resources, cleanse the air, and increase local residents' income by developing forest by-products. Additionally, feasibility studies on some aspects, including appropriate relevant policy, legislation, institutional environment, technical feasibility, the needs of local decision-makers, practical urgency, etc., are usually necessary for cost-effective adaptation measures.

Despite all the actions that can be taken, it is impossible to eliminate all losses and risks through adaptive measures, and only a proportion (albeit a considerable one) of climate risks can be justified. From Figure 1 it is straightforward to show that the loss related to climate risks slopes strictly downward in adaptive investment (Tol, 2002; Parry *et al*., 2009). Practical research on adaptation policy needs to make a cost-benefit analysis of specific measures and promote those actions which prove profitable. In contrast, for unprofitable adaptive activities, gauging potential co-benefits or long-term benefits (for instance, poverty reduction, sustainable livelihoods, and environment protection) may be of importance in getting them promoted. In the figure, the 'optimal' level of adaptation cost is where the marginal damages avoided are equal to the marginal cost, shown as the position where the curve has a slope of -45º. Further adaptation has additional benefits but the damages avoided are lower in terms of costs.

FIGURE 1

Loss from Climate Risks and benefits of Adaptation Investment



In a word, economic analysis of adaptation entails assessing and selecting adaptive measures at a sectoral or project level, analyzing the costs associated with the adaptive policy and its possible effects, appraising the combination and sequence of policy measures and estimating the funds needed to implement them. Furthermore, financial approaches should be addressed according to the context and stage of development, which means that public financial support would be more important for development-oriented adaptation than for individual or market based approaches in a poor country. For incremental adaptation, individual actions and market financial approaches could have higher net benefits, especially where risk sharing systems have been well developed – i.e. typically in a rich country.

4. Implementing Adaptive Policies and Measures in China

The Intergovernmental Panel on Climate Change (IPCC, 2007) has pointed out that climate change will leave more and more of the population exposed to threat from climate risks. The huge shortfall in adaptation and the increasing climate risks mean that developing countries and regions are faced with a more urgent need to adapt. Adaptation to climate change, whether it is incremental or developmental, will require infrastructure, technology and institutional based measures. According to the priority areas that the IPCC has identified and the problems pointed out in People's Republic of China (2007), China should promote adaptation policies and measures in the following specific fields: agriculture, coastal infrastructure and water. Each of these is considered below. We also consider some policies and measures in the field of health.

Agriculture

Although farmers are not familiar with climate change terminology or with details of the impacts, many have shown an awareness of the situation, using local knowledge to live with and adapt spontaneously to climate change in many ways. For instance, farmers adjust the timing of planting and sowing, interbreed, intercrop and increase the intensity of use of machinery, pesticides and chemical fertilizers. The existing literature shows that this autonomous adaptation activity by farmers is quite widespread and cost-effective in the sense that no other sectors or governmental involvement are needed for its implementation (Agrawala and Fankhauser, 2008). At the same time a long term adaptation plan is needed to undertake major structural changes to facilitate the changes in land-use needed to maximize yields under new conditions; application of new technologies; new land management techniques; and water-use efficiency related techniques (FAO, 2007). These adaptation measures need to be mainly supported and planned by the government, and obviously cannot be conducted by households spontaneously. Autonomous adaptation by farmers can be seen as an incremental adaptation measure, but planned adaptation driven by the government can be seen as both developmental and incremental.nd regular risks not convered yet Thus, developmental and incremental adaptation can be distinguished and economic implications can be defined accordingly.

In the context of China it should be noted first that most of the country's rural areas are more vulnerable than its urban zones. This is the case for several reasons: low income levels, a single economic structure, fragile water conservancy, flimsy housing, poor health care and insufficient social security mean that natural disasters of all kinds hurt them more**.** Crops, human life and property are threatened by extreme climate events (e.g., typhoons, floods, and droughts) due to the lack of the resources required to provide protection from and early warning of impending events. To enhance the ability to resist climate risks in the agriculture sector, given the aspects of this sector noted above, the following measures should be considered:

- Promotion of cost-effective agricultural infrastructure construction; policy incentives for local investment in water conservancy, irrigation facilities, and meteorological monitoring stations by use of financial transfer payments and market financial mechanisms;
- Reforms in the relevant laws, regulations and policies, adjustments in the structure of agricultural production; selection and cultivation of stress-resistant animal breeds and crop varieties;
- Active promotion of agricultural insurance, and investigation of risk-sharing mechanisms that integrate policy-oriented agricultural insurance and commercial insurance;
- Development of various sustainable livelihoods, for example, energy-cropping forestry, biomass energy, agro-processing and eco-tourism industries which can be supported by exploiting rural micro-financing systems so as to enhance the ability of rural areas to adapt economically.

Health

The risks from climate change make it necessary to establish mechanisms for early warning and epidemic prevention and control in China. China also faces health-related risks from climate change such as heat waves, vector-borne diseases; post-disaster health risks may also induce a predisposition to certain diseases, resulting in increasing morbidity and mortality rates, and further affecting the living environment and health conditions in some urban and rural areas (Chen *et al.*, 2005). This also suggests that pressure on present disease monitoring, prevention and treatment systems will increase. The demands for development-oriented and incremental adaptation will come from China's disease prevention and control systems simultaneously.

Consider epidemic prevention and control in coastal areas as an example: after decades of accumulation and construction, China has built up satisfactory capabilities for monitoring, prevention and control in high-incidence regions such as Guangdong province for dengue fever, malaria and other infectious diseases; nevertheless, further assessment of potential disease risks and appropriate adaptive responses are required due to potential disease risks. In addition, effective an public health system should include not only "hard-adaptation" measures such as establishing disease surveillance stations and hygiene systems, but also "soft adaptation" measures such as relevant social security policies, information sharing systems, and so on. For instance, in rural

areas, inadequate public health agencies and staff, poor sanitation and poor housing, have left rural residents threatened by a lack of safety and health. Unfortunately survival pressure on rural communities is further exacerbated by an uneven distribution of public health resources and accessibility of good quality medical services. Measures should be taken to strengthen social security and reform the existing public health system, effectively protecting health services in rural and remote areas so as to improve the adaptive capacity of rural people. To summarize, the main adaptation actions will be in the form of strengthening monitoring and control of health risks and of the medical insurance system.

Coastal Infrastructure

In conducting a cost-benefit analysis with a view to reducing climate change impacts in rising sea-level and weather extremes in coastal areas, the following issues should be taken into consideration: climate-proof investment, adaptive management, possibilities for evacuation and relocation of individuals and livestock from the flood diversion areas to secure settlements. Take sea level rise as an example: not only is its direct influence relevant but indirect and induced effects should also be taken into account when calculating the cost and benefit of adaptive measures, including back flow of seawater into river estuaries, spread of diseases, and rainstorm disasters.

It should be noted that over 70 percent of large cities in China and more than half the population are located in the eastern and coastal areas. The vulnerability of human settlements to marine disasters caused by sea level rise and typhoons has become a matter of increasing concern due to emerging climate change impacts. The State Ocean Bureau has declared that the rate of sea level rise along China's coasts in the past 50 years is 2.5 mm/annum, slightly higher than the global average. The accelerating trend of sea level rise has caused seawater intrusion, soil salinization and coastal erosion, has damaged the typical marine ecosystems of coastal wetlands, mangrove swamps and coral reefs, and has given rise to a great negative impact on production and on the lives of coastal people. The eastern coastal areas are also frequently hit by climate disasters such as typhoons and floods.

A report by the Organization for Economic Cooperation and Development (OECD) ranks coastal cities at risk from flooding in terms of total social assets. A number of Chinese cities including Guangzhou, Shanghai, Tianjin, Hongkong and Qingdao-are ranked in the top 20 most vulnerable cities. In coastal areas, adaptive measures could take a wide variety of forms. Project-based measures include building sea walls, flood control facilities, strengthening buildings and evacuating people and property; technological measures could include the improvement of water resource management, changes in the modes of agricultural and fish production in coastal areas (Promoting the adoption of new varieties of flood and saline-alkali resistant crop seeds); institutional measures may include standards, legislation, tax subsidies, property insurance, etc. Furthermore, it is vital to study the migration and urban planning issues posed by rising sea level and to investigate the prevention costs for public facilities as well as specific measures to enhance the government's risk management capacity.

Water Resources

Water scarcity and water pollution are the most severe environmental problems that China faces today. Regional hydrological infrastructure investment for reducing the risk of floods and drought may constitute both incremental and development-oriented adaptation. The cost of such adaptation measures includes the investment and socio-economic costs of all kinds of adaptive activities, while the benefits comprise more security and avoidance of damage to crop production, life, and property. It must also be noted that while national or regional hydrological engineering projects are mainly designed as a public welfare activity, in some local areas the trading of water property rights can be considered as a good case of a marketing adaptive behavior. Even though market behaviors are mainly spontaneous and individual based, the costs and benefit of development-oriented and incremental adaptation can still be clearly distinguished.

The main adaptation measures must therefore consist of improvements in water resource management and environment protection. China's major rivers are undergoing a decrease in runoff related to climate change, which will further exacerbate ecosystem degradation and land desertification in arid regions, and hence pose a direct threat to water security. Some key projects such as large-scale afforestation, returning farmland to forest and grasslands and water-saving irrigation measures are undoubtedly effective in improving the overall ecological environment; however, practice has made it clear to us that we need to further assess the impacts of these measures on rural populations in arid areas at social, economic and ecological levels so as to identify and establish more effective prevention and response measures through experience and lessons learnt.

In the field of water resource management and environment protection, engineering adaptation measures include river dredging, grass/tree planting, and applying the ecosystem approach to protect wetlands and remedy water pollution. In addition, the following institutional adaptation measures are important: (a) establishing a rational, scientific water pricing mechanism for responding to climate change involving the development of water-saving products and improvement of demand-side management; (b) combining water resources management, environment protection and sustainable livelihoods to establish integrated ecosystem watershed governance in several major river basins; (c) vigorously promoting the watershed eco-compensation mechanism, expanding channels for adaptation funding, so as to enhance capacity-building from the institutional environment.

5. Discussion and Conclusions

Due to the wide scope of adaptation to climate change, most of the literature to date regards all climate/weather-related actions as climate change adaptation. This has the advantage of being simple but is not necessarily correct. Another confusion that emerges in the literature is between adaptation and development. By distinguish-

ing between incremental adaptation and development-oriented adaptation explicitly, this study seeks to contribute to clarifying the major issues of adaptation, such as responsibility for climate change, sources of adaptation funds, key stakeholders for adaptation and other fundamental issues. Moreover, in this paper, we categorize adaptation measures as infrastructure-based, technology-based and institutional in their approaches to enhance adaptive capacity. Within this framework, taking China as an example, this paper provides an analysis of adaptation to climate change as relevant to that country.

It is within this broad framework that policy options need to be evaluated, with the use of economic analysis along the lines indicated to provide the actual operational components of the plan. From a policy and economic perspective, this paper offers some typical examples of adaptation activities under an explicit conceptual framework, and highlights the importance of policy guidance and an enabling environment as well. This paper does not refer to specific adaptation planning with cost-benefit analysis (this will be further explored in upcoming research) but it strives to develop this analytical framework based on some specific cases**.**

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